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AC Impedance Testing on 40-Ah Li-Ion Cells

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SMC/AXE

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14. ABSTRACT

The objective of this report is to summarize the initial data from AC impedance testing on 40-Ah Li-Ion cells. This report examines cells with the same manufacturer and differing locations. Cells from one location have measurements taken before any testing or cycling of the cells was performed. Cells from the second location have measurements taken only after cycling. The measurements were taken at SOC between 3.18 V and 3.59 V. All measurements were taken at room temperature. This data will be useful as a baseline against which future measurements can be compared.

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Lithium-ion, AC impedance, Batteries

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1. Introduction

AC impedance has been shown to successfully model certain aspects of Li-Ion cells. In order to better understand the capabilities of this technique, it is necessary to measure the cells as they progress through testing. A baseline measurement of each cell is required so that individual cell characteristics can be accounted for as anomalies and variations in cell performance arise. This report summarizes the initial baseline data on the cells for future comparison.

Thirty-four cells from four lots of 40-Ah Li-Ion cells are characterized by the AC impedance technique. Two graphs are presented for each cell. The first graph, a Nyquist plot, is useful for determining what type of effect, whether it be a capacitive or inductive element, for example, is responsible for features on the graph. The second graph, a Bode plot, is more detailed, explicitly includes frequency, and is generally more useful but harder to interpret. Specific values of resistances and capacitances can be extracted from the data based upon an electrochemical model of the cell. More detailed analysis is presented in the ATR *Initial Study of 40-Ah Li-Ion Cyclindrical Cell by AC Impedance Spectroscopy.*

2. Group HE5424-xx

These 10 cells were received on January 16th 2001. Initial characterizations were performed on them in September of 2002 where they had an average capacity of 48.38 Ah at 25°C (C/2 rate). There has been no further testing on cell numbers 2, 5, 6, 7, and 27. Cell 1 was charged to 3.6 V on 5/27/03; Cell 26 was charged on 3/5/04. Cells 3 and 4 underwent additional testing. Figures 1 and 2 show the Nyquist and Bode plots, respectively.

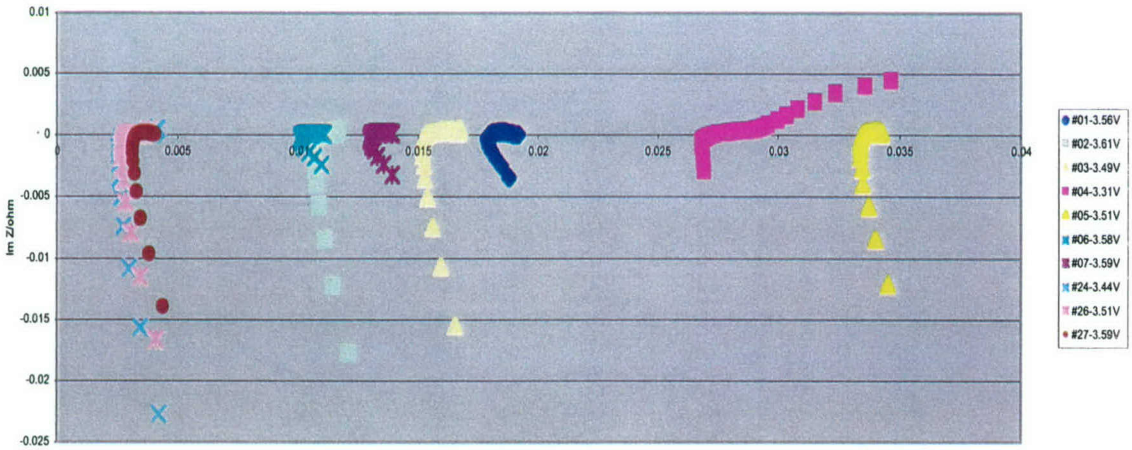

Figure 1. Nyquist plots for group HE5424-xx.

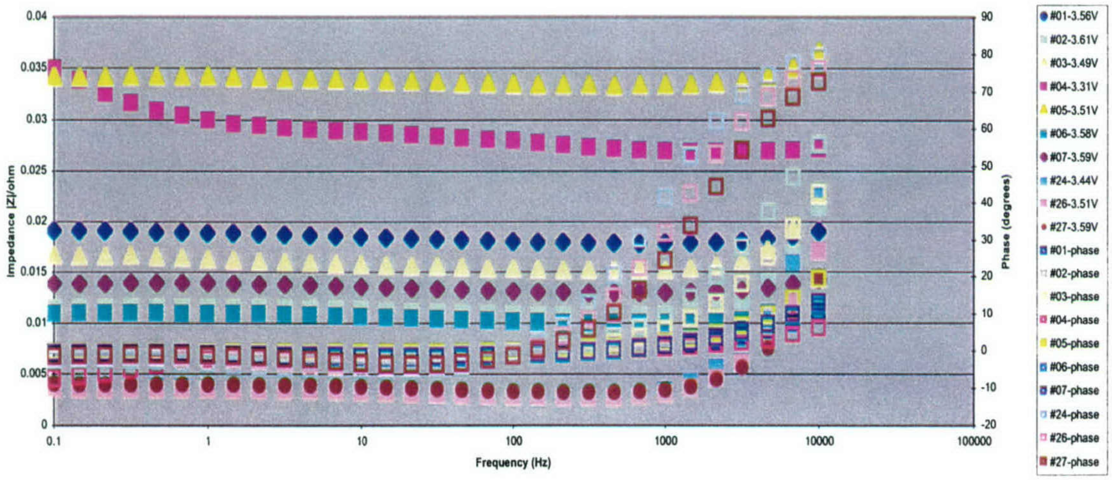

Figure 2. Bode plots for group HE5424-xx.

3. Group HE5424-xxx

These 6 cells were received on July 25 2002. Initial characterization was performed on them in October of 2002 where they had an average capacity of 49.80 Ah at 25°C (C/2 rate). There has been no further testing on cell numbers 127,132,135, and 136. Cell 128 was put on test and charged to 3.6 V on 3/21/03 and again on 6/8/04. Cell 131 was charged to 3.6 V on 12/02/03. Figures 3 and 4 show the Nyquist and Bode plots, respectively.

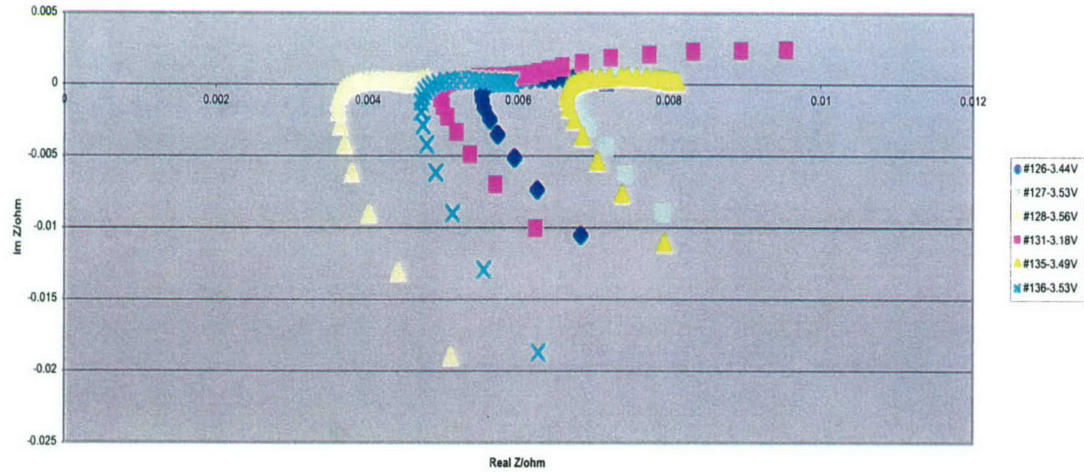

Figure 3. Nyquist plots for group HE5424-xxx.

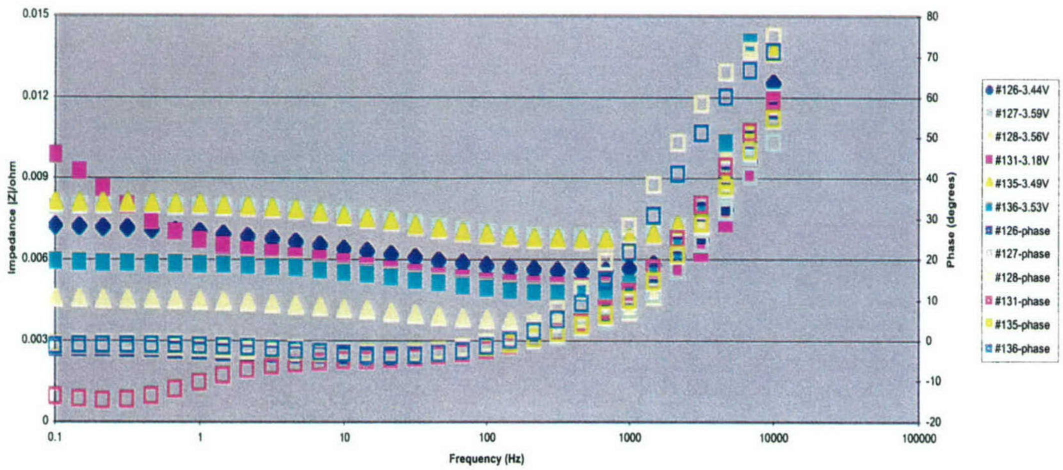

Figure 4. Bode plots for group HE5424-xxx.

4. Group M20xx

These 4 cells were received on January 29, 2003. These cells are intended for launch vehicle applications. No tests have been run on these cells. Cells 53 and 71 were charged to 3.6 V on 1/27/03 and 10/30/03, respectively. Cell 92 was charged on 3/21/03 and 1/05/04. Cell 93 was charged on 5/27/03 and 6/08/04. Figures 5 and 6 show the Nyquist and Bode plots, respectively.

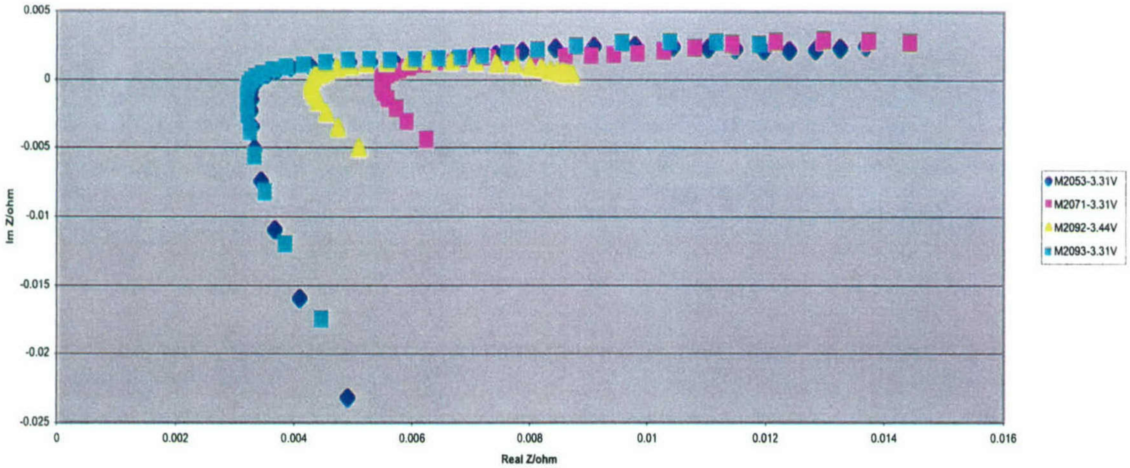

Figure 5. Nyquist plots for group M20xx.

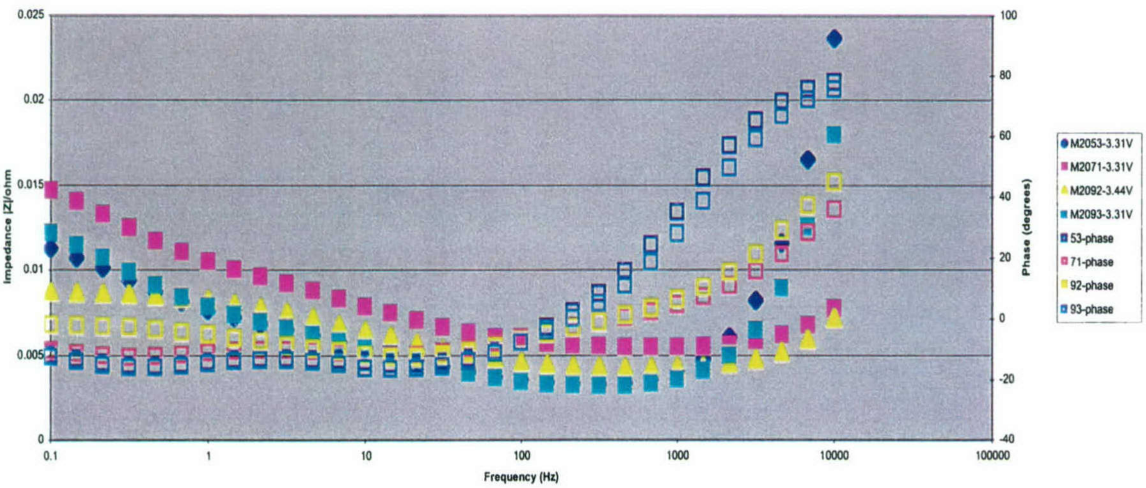

Figure 6. Bode plots for group M20xx.

5. Group M047xx18

These 12 cells were manufactured at a different location from the others. Impedance testing was done immediately before and after initial characterizations. Initial characterizations were performed on them in March of 2004 where they had an average capacity of 40.33 Ah at 25°C (C/2 rate). Figures 7 and 8 show the Nyquist plots before and after acceptance testing. Figures 9 and 10 show the Bode plots before and after acceptance testing.

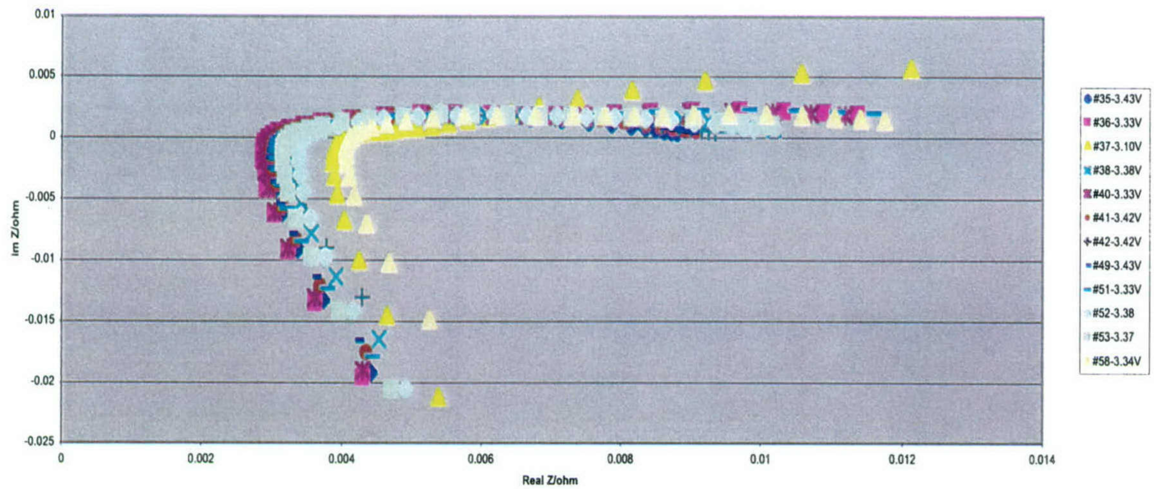

Figure 7. Nyquist plots for group M047xx18 before acceptance testing.

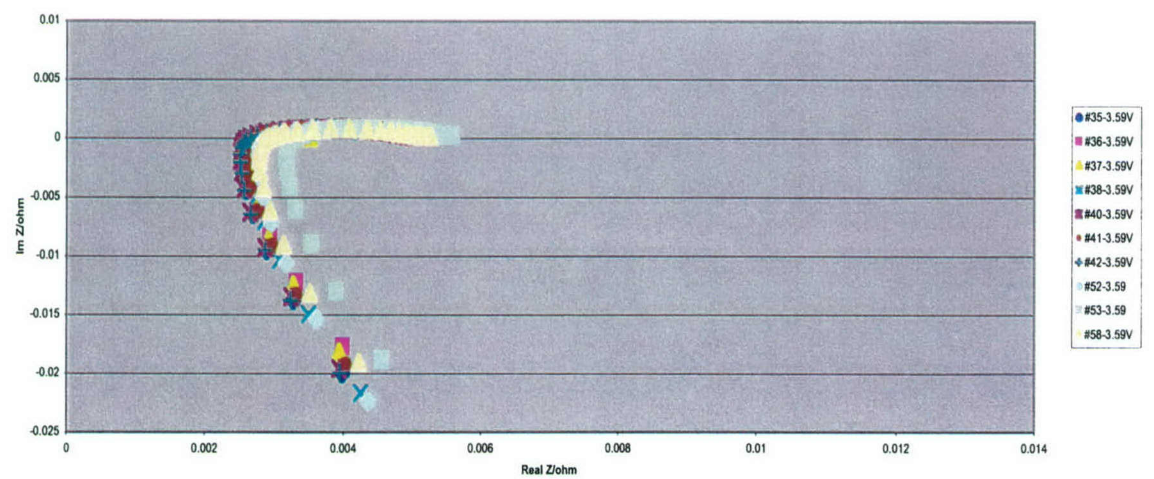

Figure 8. Nyquist plots for group M047xx18 after acceptance testing.

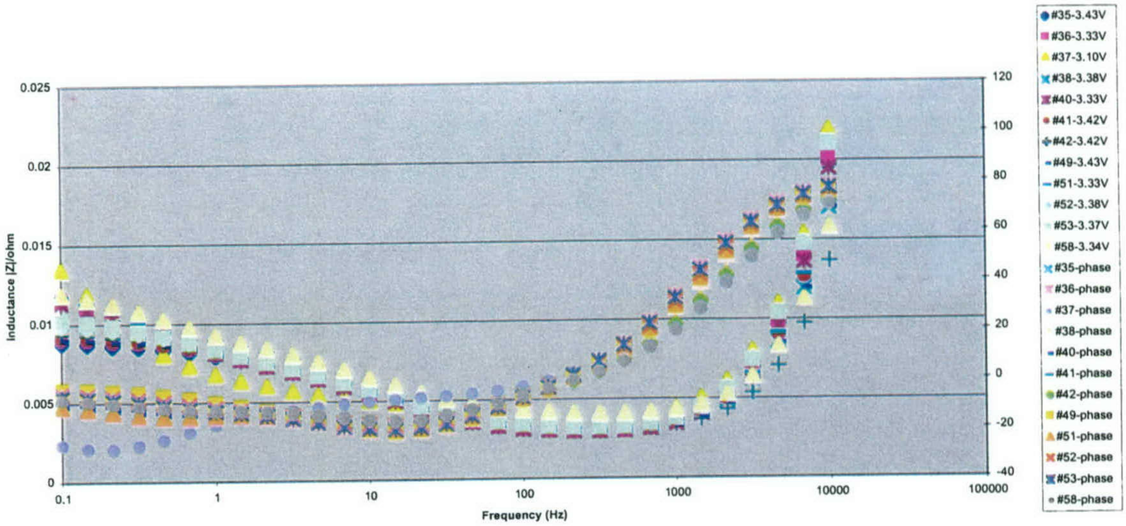

Figure 9. Bode plots for group M047xx18 before acceptance testing.

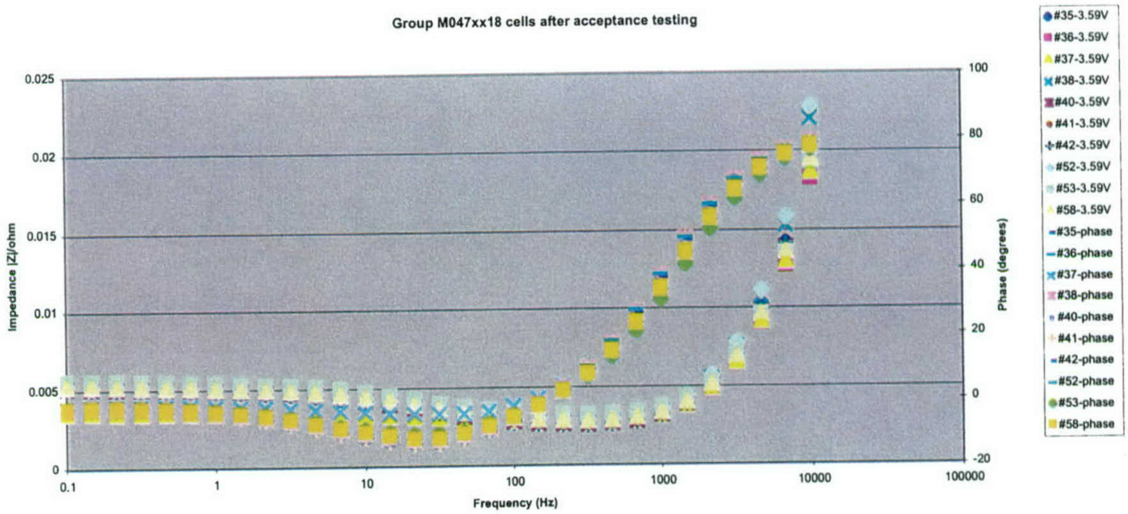

Figure 10. Bode plots for group M047xx18 after acceptance testing.

6. Discussion

Thirty-four 40-Ah Li-Ion cells have been characterized by AC impedance testing. This includes cells manufactured at two locations as well as different lot numbers from the respective manufacturers. The data show a similar form for all cells with strong variations due to SOC. Offsets on the real axis of the Nyquist plot can be explained by different configurations of attachment leads. Some variation is also expected due to the internal resistance of the battery. This can be most clearly seen in the M047xx18 testing where the leads were attached in a similar manner. Baseline data have been presented for future comparisons. These tests will continue over the life of the cells and will aid the understanding of degradation modes in the cell. Further testing at various states of charge and temperatures has also started and is presented elsewhere.

LABORATORY OPERATIONS

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Space Materials Laboratory: Evaluation and characterizations of new materials and processing techniques: metals, alloys, ceramics, polymers, thin films, and composites; development of advanced deposition processes; nondestructive evaluation, component failure analysis and reliability; structural mechanics, fracture mechanics, and stress corrosion; analysis and evaluation of materials at cryogenic and elevated temperatures; launch vehicle fluid mechanics, heat transfer and flight dynamics; aerothermodynamics; chemical and electric propulsion; environmental chemistry; combustion processes; space environment effects on materials, hardening and vulnerability assessment; contamination, thermal and structural control; lubrication and surface phenomena. Microelectromechanical systems (MEMS) for space applications; laser micromachining; laser-surface physical and chemical interactions; micropropulsion; micro- and nanosatellite mission analysis; intelligent microinstruments for monitoring space and launch system environments.

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